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None

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UK CL (Edition I) G1A AEE AEN
INT CL^4 G01B

(54) **Optical device for the remote measuring of variations in the orientation of an object**

(57) The device, which can be used in particular for measuring the variations in the end part of a gun tube (10) with respect to a support, comprises a reflector (12) carried by the object and a light source-detector assembly (16) carried by the support at a location such that the said variations cause the displacement of an image of the source on the detector. In order to measure the variations in orientation about a single direction, the reflector comprises a single dihedron (12) whose edge is perpendicular to the said direction and whose peak angle differs from 90° by a small angle β and the source comprises at least one pulsed light emitter offset from the detector, in the said direction, by a distance $a = 2f\beta$, where the dihedron consists of two reflecting silvered surfaces and f is the focal length of the collimator, and by a distance $a = 2nf\beta$ where the dihedron is a total reflection prism and n is the index of the material forming the prism.

FIG.1.

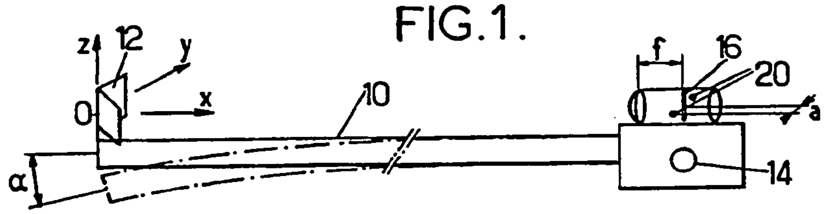

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FIG.1.

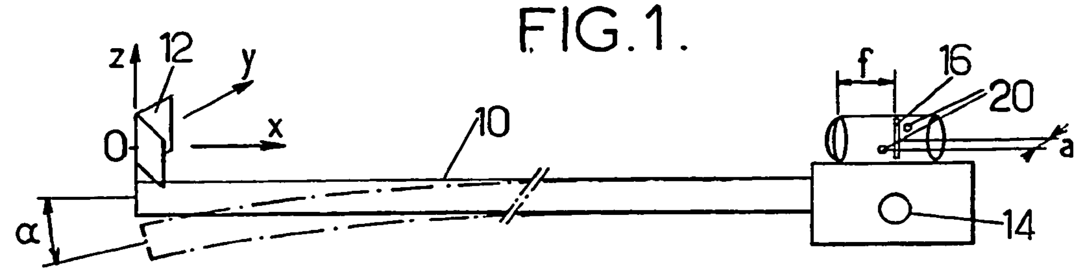


FIG.3.

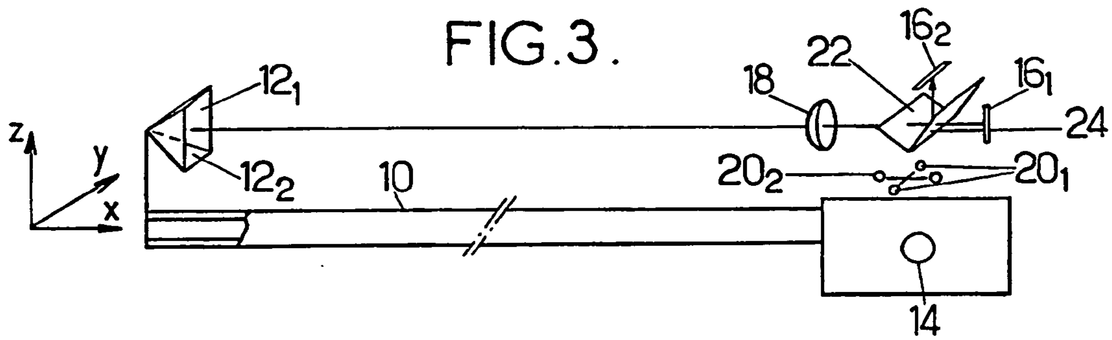


FIG.2.

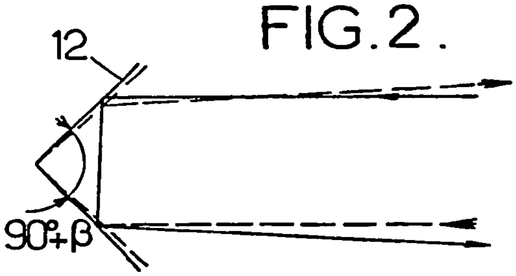


FIG.4.

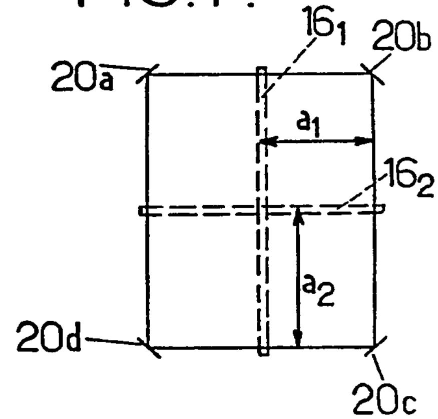


FIG.5.

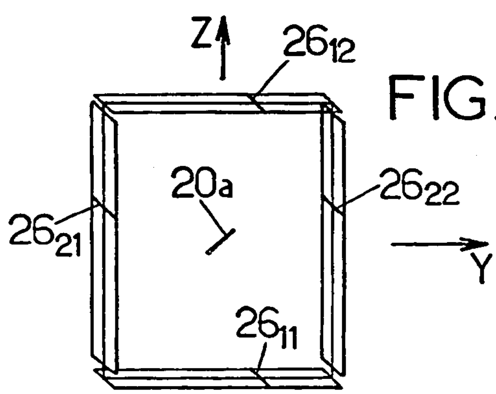


FIG.6.

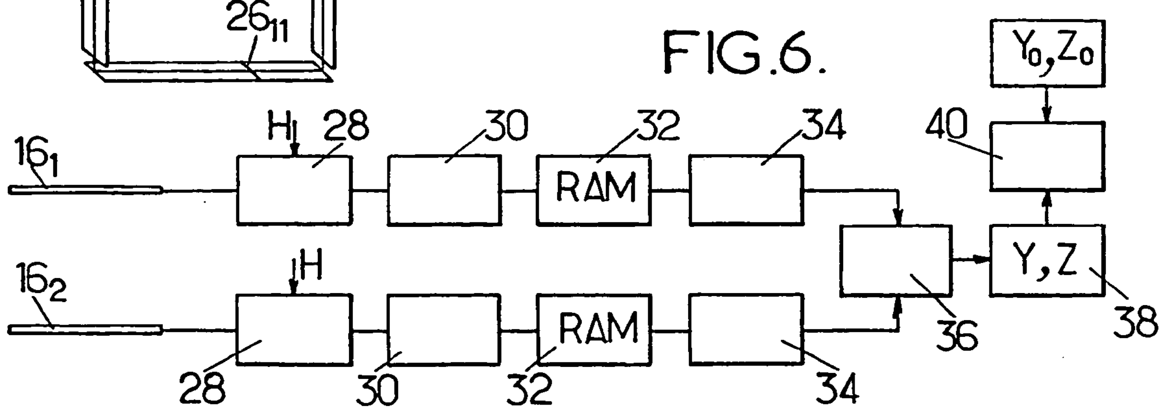


FIG. 7.

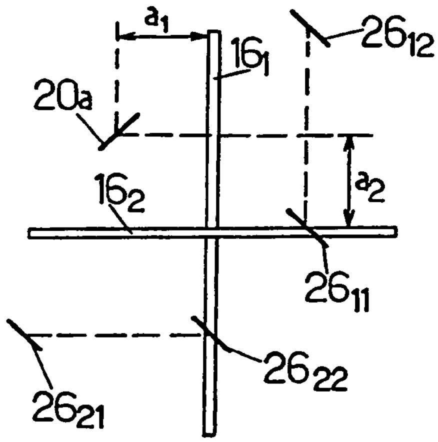


FIG. 8.

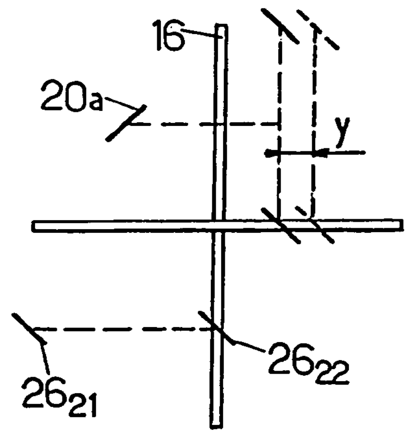


FIG. 9.

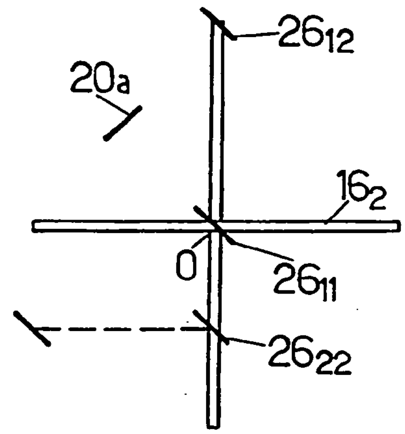


FIG. 10

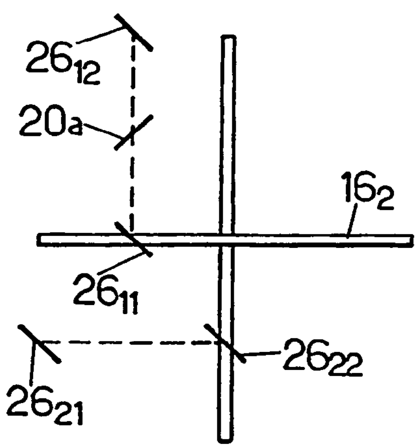


FIG. 11.

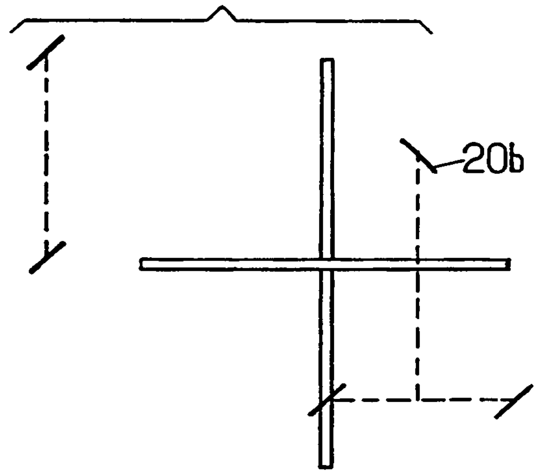


FIG. 12.

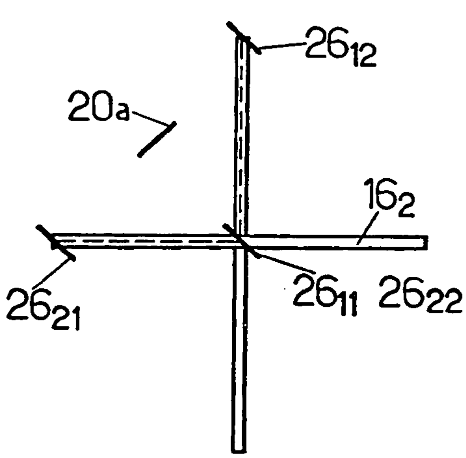
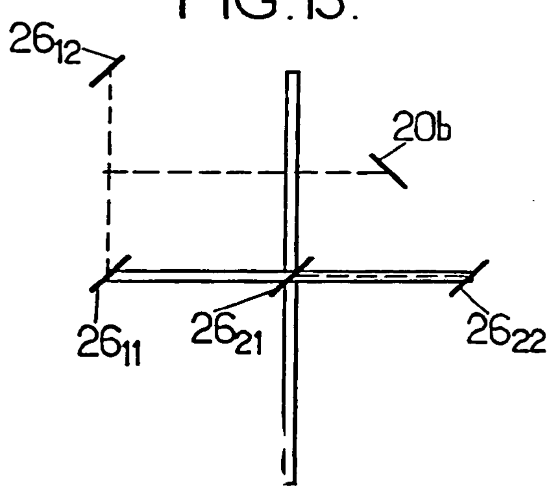


FIG. 13.



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OPTICAL DEVICE FOR THE REMOTE MEASURING OF VARIATIONS IN THE ORIENTATION OF AN OBJECT.

The subject of the invention is a device for the remote measuring of variations in the orientation of an object with respect to a reference support and it has an important application, though not exclusive, in the measurement of variations in a line of sight caused by the flexion of a tube.

There are already known such measuring devices of the type comprising a reflector carried by the object and an assembly having a collimator light source and a detector carried by the support, at a location such that the variations in orientation cause the displacement of an image of the source on the detector. In particular, such devices have been produced for measuring the distortions in the chase of a gun. The assembly is mounted close to trunnions enabling the gun to be adjusted in elevation while the reflector is mounted on the chase in the immediate proximity of the mouth.

The existing devices give satisfactory results when the firing support is fixed. On the other hand, they are poorly suited for the measurement in the presence of vibration or when a large dynamic measurement range is required.

The invention is intended to provide a device capable of functioning in a vibratory environment, at a high measurement repetition rate and with an accuracy that is also high over a wide dynamic range of variation.

For this purpose, the invention in particular relates to a device of the type defined above, characterized in that, in order to measure the variations in orientation about a specified direction, the reflector comprises a dihedron whose edge is perpendicular to the said direction and whose peak angle differs from 90° by a small angle β and the source includes at least one pulsed light

emitter offset from the detector, in the said direction, by a distance $a = 2f\beta$, where f is the focal length of the collimator.

The dihedron can in fact be formed by any reflecting device of the type frequently called 'invariant', of which the best known example is that formed by two reflecting surfaces at 90°, such as two silvered surfaces or two surfaces of a total reflection prism. In the second case, the distance a to be used according to the invention is $a = 2nf\beta$, n being the index of the material forming the prism.

In general, two sources are placed symmetrically with respect to the detector. Consequently, the dihedron will provide a total of four images (two per source). The device can then be completed by means associated with the detector enabling the selection from the sources of the one for which a significant result is obtained.

When the device is intended for measuring the variations in orientation about two directions orthogonal to each other, it comprises two dihedrons whose edges are orthogonal, providing a total of four images of each source. The detector can be formed by one strip for each direction: the two strips having to be orthogonal and both in the focal plane of the collimator; a light separator is placed behind the collimator.

In the case of measurement in two perpendicular directions, it is advantageous to provide four light sources placed at the corners of a square or of a rectangle around the optical axis of the collimator and to provide means of sequential switching on of the four sources. When it is necessary to use a high measuring rate, the sources will generally be laser diodes.

The invention will be better understood on reading the following description of particular embodiments, given as non-limiting examples. The description refers to the accompanying drawings among which:

Figure 1 is a basic diagram of a device for measuring variations in orientation of the end part of a tube, about a single direction;

Figure 2 is a basic diagram showing the formation of two images with a quasi-invariant dihedron from an object source;

Figure 3 is similar to Figure 1 and is a diagram of a device enabling the measurement of the variations in orientation about two orthogonal directions;

Figures 4 and 5 show the various parameters which have an effect in the functioning of the device;

Figure 6 is a block diagram of electronics which can be used in the device of Figure 3; and

Figures 7 to 13 illustrate various image arrangements obtained from the device having four sources as illustrated in Figure 4.

The device whose optical part is shown diagrammatically in Figure 1 can be used for measuring the variations in orientation of the end part of the chase of a gun, for example mounted on an armoured vehicle. This device includes an assembly carried by a support which serves as a reference, generally the part of the gun directly supported by the turret, and a reflector mounted near the mouth of the gun on the chase 10.

The reflector is formed, in a way that is known in itself, by a dihedron 12 whose edge is placed along the direction z, which is vertical when the elevation aiming is zero. The dihedron is symmetrical with respect to the direction x, parallel to the axis of the chase.

The assembly carried by the reference support, placed in the immediate proximity of the trunnion 14 about which the weapon rotates during aiming in elevation, includes, in the illustrated embodiment, a detector 16 formed by a strip of photosensitive elements, for example a strip of photodiodes or charge couple detectors. The strip is mounted in such a way that, in the absence of flexion of the chase 10, it is parallel to the direction z and in the plane defined by Ox and Oz (O being the centre of the edge of the dihedron 12). The strip is located in ——————

the image plane of a collimator 18, of focal length f.

The assembly also includes, in the illustrated embodiment, two sources 20 placed symmetrically with respect to the strip 16, at a distance a from this strip.

Whilst the dihedrons used as backward reflectors usually have an angle of 90^o, the dihedron 20 is provided in order to give, of each source 20, two images of which one is formed on the strip 16, at a distance from the centre of the strip which changes according to the orientation of the end part of the chase 10 about the direction y. In practice, the dihedron 12 is given an angle which differs from 90^o by a small deviation β (not exceeding a few degrees) chosen as a function of a and of f such that:

$$2f\beta = a$$

When the two surfaces of the dihedron are formed by the reflecting surfaces of a total reflection prism, this formula becomes:

$$2nf\beta = a$$

where n is the index of the material forming the prism.

The dihedron 12, which can be considered as a quasi-invariant dihedron, enables the source (or sources) 20 to be offset from the strip in the focal plane and therefore gives two images of each source 20, offset by $4nf\beta$ in the focal plane, which contains the sources 20 and the detector. The two images move parallel to each other when the angle α between the end part of the chase 10 and its theoretical direction changes. One of the images of each source remains on the detector 16 and moves along this detector.

It is always certain that there will be one image on the detector, provided that the flexion does not exceed the value for which the image of the source reaches the edge of the strip.

Figure 3 shows a device with four sources 20_1 and 20_2, which can be used when it is required to measure

the variations in orientation about two orthogonal directions y and z. The device includes, in addition to the pair of sources 20_1 having the same arrangement as those of Figure 1, two sources 20_2 aligned along an orthogonal direction. Each pair of sources is associated with the corresponding detector 16_1 or 16_2 from two detectors arranged orthogonally to each other.

In order for it to be possible to place the two detectors, also formed by strips, in the focal plane, the device of Figure 3 includes two separating plates 22 and 24. The semitransparent plate 22 transmits the light emitted by the sources 20_1 and 20_2 by reflection, and, on return, allows part of the light to pass through towards the detectors 16_1 and 16_2. This transmitted light is divided into two sections by a second plate 24.

Another solution consists of using two different collimators on emission and on reception, such that the object focal plane and the image focal plane are offset with respect to each other in the direction x, which makes it possible to dispense with the plate 22.

The sources 20_1 and 20_2 can be arranged in a rectangle those sides are parallel to the strips, as shown in Figure 4. This arrangement enables the dynamic measurement range to be increased as any deviation with respect to the centred position tends to bring back two of the four images of each of the sources, provided by the two quasi-invariant dihedrons 12_1 and 12_2 of the centre O. The use of four sources arranged in this way will generally be the best possible compromise, although this number can be reduced or increased, for example by using two sets of sources, the sources of one set being at the tops of a rectangle, and the others being in alignment with the first ones. When the sources are not point sources but of slit shape, they can be arranged as shown in Figure 4 or otherwise, for example such that each source is in the form of a slit directed towards the centre O.

As shown in Figure 5, this arrangement provides four images of each source 20, images which, when there is a change in orientation of the quasi-invariant dihedrons, are displaced in parallel and in pairs and parallel to the corresponding detectors. Figure 5 diagrammatically represents the four images 26_1 and 26_2 corresponding to a given deflection of the tube 10. Because of the presence of four sources 20 having the arrangement shown in Figure 4, it is certain that one image will be formed on each of the detectors 16_1 and 16_2.

In addition, the arrangement of Figure 4 enables it to be certain that two images, which do not overlap, of one of the sources 20 will always be available.

The device can include a results analysis circuit, of the type shown in Figure 6, associated with means of covering each of the four sources 20 in a repetitive cycle. Each of the two strips is associated with a measuring branch which can be formed from a reader 28, activated at the rate of a clock H which also fixes the lighting frequency, an analog/digital converter 30 providing a digital value representing the illumination received by each sensitive element of the detector 16. All of the results are loaded into a buffer memory 32 and, after the strip has been scanned, the barycentre is determined by a computing circuit 34. In this way there are obtained, for each cycle of illumination of the four sources in succession, data representing the position of the image in the Y and Z directions (Figure 5). A selection circuit 36 receives the data coming from the two branches and selects the most significant values (those for which the illuminated source forms an image on one or two strips 16_1 and 16_2). The values Y, Z are stored in 38 and a circuit 40 enables these values to be compared with values Y_0, Z_0 obtained by a harmonization process and corresponding to the non-deflected state of the tube 10.

Such a device is particularly applicable to the

measurement of distortions on the chase of a gun. It enables a measurement to be obtained, over a chase of several metres, with a resolution of the order of 30 micro-radians for movements of flexion which can be as much as 14 mils peak-to-peak. The measurement frequency can easily be as much as 500 Hz when the sources used are laser diodes providing light pulses of 200 nanoseconds with a repetition period of 10 milli-seconds. When Ga-As laser diodes are used as sources and detectors 16 formed from "RETICON" strips of 256 elements in 25 micron steps are used, it is possible to group the elements carried by the carriage inside a cylinder of a few millimetres diameter, with a collimator of focal length 250 mm. The device can also be adapted, but with a smaller dynamic measuring range, to the measurement of torsional distortions.

Some typical examples of image arrangements will now be described for illustrating how such arrangements can be analyzed for obtaining a significant measurement even when a plurality of images are formed on a same linear array of sensors.

It will be assumed that the device has four sources 20a, 20b, 20c, 20d arranged as indicated in Figure 4.

The operating process implies a standardization phase, then successive measurements each including a measurement sequence. During standardization and during measurement, only one source is lighted at a time and its image is acquired on the two linear arrays 16_1 and 16_2.

Referring to Figure 7, the four images of source 20a which are obtained when this source is lighted while the tube has no flexure (α being a zero in plane xOz and in plane xOy) are shown. Image 26_{11} (one of the two images corresponding to azimuth detection) and image 26_{22} (one of the two images corresponding to elevation detection) are formed on linear arrays 16_2 and 16_1, respectively. The reading unit 28 measures the output signals of the sensors in succession, at the clock rate, and delivers

them to the analog-digital converter 30. In a simplified embodiment (not shown) which may be used when the image has a size of the same order of magnitude as that of an individual sensor, the reading device may include a threshold circuit and then it delivers a binary output signal. Then it is sufficient to store the serial number of the sensor (or of the adjacent sensors) for which the output signal indicates there is an image.

For simplification, the latter case only will be considered in the following. The serial number of the sensor which receives the image in a linear array is stored.

Since there is no flexure, the position of images 26_{11} and 26_{22} constitutes a reference position for the latter deformation measurements. The other images are out of the linear arrays and are consequently not detected.

The same determination of reference positions is carried out for all sources in succession, for complete standardization.

Referring to Figure 8, the change in the positions of images of source 20a when there is a flexure in the azimuth plane (ie. in plane yOz) is illustrated. As shown, images 26_{11} and 26_{22} have moved toward the left over a distance y_a while the elevation images 26_{21} and 26_{22} have not moved. The serial numbers of the new sensors which receive the images are stored.

The measure is repeated for the other three sources. Then, for computing the elevation flexure, four results $\underline{y}$ are available. The angle of flexure is proportional to:

$1/4\ (y_a + y_b + y_c + y_d)$.

There is no ambiguity, since there is a single image on each linear array.

On the other hand, an ambiguity may occur if a plurality of images are formed on a same linear array. However, the difficulty may easily be removed. Referring for instance to Figure 9, the value of the azimuth flexure

is such that image 26_{11} (and possibly 26_{12}) is formed on linear array 16_1, in addition to image 26_{22}.

However, it will be appreciated that the image 26_{22} only may be formed under the cross-point 0. Then the selector 36, which has to select between two or three measurements, may be programmed for retaining only image 26_{22} by applying a simple test.

Figures 10 and 11 illustrate the images of sources 20a and 20b when the azimuth flexure has such a value that no image of one of the two sources (source 20b as illustrated) is formed on linear array 16_2. Then, the azimuth measurement will be carried out by using only those values y which are available, that is the images provided by sources 20a and 20d. There is no ambiguity, since the images 26_{11} of sources 20a and 20d are found at locations where only such images can be found.

In short, the flexure can always be measured by determining the average value of a plurality of measurements.

Last, Figures 12 and 13 respectively illustrate the images formed by sources 20a and 20b if the elevation and azimuth amounts of flexure have such a value that two images are formed at the cross-point of the two linear arrays. Again, the ambiguities may be removed by the same process as above, for instance, image 26_{11} of source 20b is formed in a zone where none of the other three images can be found. By successively eliminating images, it is possible to determine the useful images and the deformations may be found by averaging three measurements.

The invention is capable of having numerous variants and numerous applications other than that which has just been mentioned. In particular, it is applicable to any measurement of angle variation, for example for the purpose of determining changes in the position of lines of sight and those of a support arm. It also enables harmonizations of axes and stabilization residual measurements to be carried out.

CLAIMS

1. Device for the remote measuring of variations in the orientation of an object with respect to a reference support, comprising a reflector carried by the object and a light source-detector assembly carried by the support at a location such that the said variations cause the displacement of an image of the source on the detector, characterized in that, in order to measure the variations in orientation about a specified direction, the reflector comprises a dihedron whose edge is perpendicular to the said direction and whose peak angle differs from 90^o by a small angle β and the source includes at least one pulsed light emitter offset from the detector, in the said direction, by a distance $a = 2f\beta$, where f is the focal length of the collimator.

2. Device according to Claim 1, characterized in that two sources are placed symmetrically with respect to the detector.

3. Device according to Claim 1, intended for measuring the variations in orientation about two specified orthogonal directions, characterized in that it comprises two dihedrons whose edges are orthogonal to each other, providing a total of four images of each source and two detectors.

4. Device according to Claim 3, characterized in that it comprises four light sources arranged at the corners of a square or of a rectangle around the optical axis of the collimator.

5. Device according to Claim 4, characterized in that it includes means for the sequential switching on of the four sources.

6. Device according to Claim 4 or 5, characterized in that there are means of selection of the measurement corresponding to the source providing images on each of the two detectors.

7. Device according to any one of Claims 3 to 6,

characterized in that it comprises a single collimator and light separating means enabling the two detectors to be placed, in the form of crossed strips, in the focal plane of the collimator.

8. Device according to any one of the preceding claims, characterized in that the detector, or each detector, is formed by a strip of photodiodes and in that the source, or each source, is formed by a laser diode.

9. A device for the remote measuring of variations in the orientation of an object with respect to a reference support substantially as described hereinbefore with reference to and as illustrated in the accompanying drawings.

Amendments to the claims have been filed as follows

1. Device for the remote measuring of variations in the orientation of an object with respect to a reference support, comprising a reflector carried by the object and a light source-detector assembly carried by the support at a location such that the said variations cause the displacement of an image of the source on the detector, characterized in that, in order to measure the variations in orientation about a specified direction, the reflector comprises two reflecting surfaces forming a dihedron whose edge is perpendicular to the said direction and whose peak angle differs from 90° by a small angle β not exceeding a few degrees, chosen as a function of _a_ and of _f_ such that $a = 2f\beta$ or $a = 2nf\beta$ when the dihedron is formed by the reflecting surfaces of a total reflection prism (n being the refractive index of the prism) and the source includes at least one pulsed light emitter offset from the detector, in the said direction, by a distance $a = 2f\beta$, where f is the focal length of a collimator of said light source detector assembly.

2. Device according to Claim 1, characterized in that two sources are placed symmetrically with respect to the detector.

3. Device according to Claim 1, intended for measuring the variations in orientation about two specified orthogonal directions, characterized in that it comprises two dihedrons whose edges are orthogonal to each other, providing a total of four images of each source and two detectors.

4. Device according to Claim 3, characterized in that it comprises four light sources arranged at the corners of a square or of a rectangle around the optical axis of the collimator.

5. Device according to Claim 4, characterized in that it includes means for the sequential switching on of the four sources.

6. Device according to Claim 4 or 5, characterized

in that there are means of selection of the measurement corresponding to the source providing images on each of the two detectors.

7. Device according to any one of Claims 3 to 6,

characterized in that it comprises a single collimator and light separating means located behind the collimator and enabling the two detectors to be placed, in the form of crossed strips, in the focal plane of the collimator.

8. Device according to any one of the preceding claims, characterized in that the detector, or each detector, is formed by a strip of photodiodes and in that the source, or each source, is formed by a laser diode.

9. A device for the remote measuring of variations in the orientation of an object with respect to a reference support substantially as described hereinbefore with reference to and as illustrated in the accompanying drawings.

PATENTS ACT 1977
EXAMINER'S REPORT TO THE COMPTROLLER
UNDER SECTION 17(5)
(The Search Report)

15

Application No. 8703802

FIELD OF SEARCH: The search has been conducted through the relevant published UK patent specifications and applications, an applications published under the European Patent Convention and the Patent Co-operation Treaty (and such other documents as ma be mentioned below) in the following subject-matter areas:-

UK Classification G1A (AEE, AEN)

(Collections other than UK, EP & PCT:) Selected US specifications held under G1A (EG, EN)

DOCUMENTS IDENTIFIED BY THE EXAMINER (NB In accordance with Section 17(5), the list of documents below may incluc only those considered by the examiner to be the most relevant of those lying within the field (and extent) of search)

Category	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

CATEGORY OF CITED DOCUMENTS

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E patent document published on or after, but with priority date

Search examiner

J S BOOTH

Date of search

9 September 1987